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FREQUENCY AND FORCE EFFECTS ON PSYCHOPHYSICAL AND MYOELECTRIC VARIABLES IN LOW- INTENSITY PINCHING TASKS

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Force and frequency in manual handling tasks are known risk factors for work related upper arm disorders. Three force levels and three frequencies are used to define the external load in a pinching task. The effects of these external loads on subjective and objective responses are studied. Subjective ratings poorly reflect the levels of external load. EMG variables P50 en P10 of the prime mover muscle seem useful variables in evaluating the effects of task frequency above a certain threshold in task frequency. P90 of the prime mover muscle is useful in evaluating the effects of external forces. It can be concluded that the P50 does not reflect the differences in force levels in tasks with low intensities.

INTRODUCTION

Repetitive Strain Injuries (RSI), Cumulative Trauma Disorders (CTD) or Work Related Upper Limb Disorders (WRULD) are terms for a range of muscle, tendon and nerve disorders of the upper arm and neck. There is a tendency towards an increasing occurrence of these disorders in office work as well as in agricultural and industrial work (Bernard, 1997, Brogmus, 1996, Cherniak, 1996, Otten, 1997). There is consensus that repetitiveness, exerted forces, and hand/arm postures are associated with these disorders (Bernard, 1997, Silverstein et al., 1987, Silverstein & Armstrong, 1986, Kurppa et al, 1991). The relative contribution of these risk factors and others (e.g. task precision and movement velocity) is not clear.

The etiology of these disorders is to a large extent unknown. Conceptual models for the pathogenesis are proposed describing sets of cascading exposure, dose, capacity and response variables (Armstrong et al., 1993, Westgaard et al., 1996). In Figure 1 a simple model of the development of complaints is presented. In this model it is assumed that task characteristics lead to an internal load, leading to acute responses followed by effects on health (signs and symptoms).

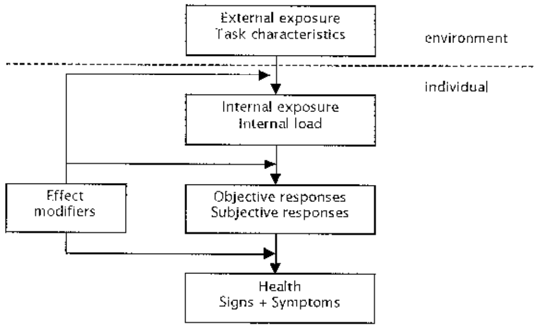

Figure 1 Conceptual model of the relationship between task characteristics and health signs and symptoms (based on Westgaard et al., 1996)

Electromyography (EMG) is often used to quantify objective responses. The Amplitude Probability Distribution Function (Jonsson, 1978), can be used to calculate three myolectric variables, the static activation level P10, the median activation level P50 and the peak activation level P90. Each variable can be an indicator of the risk of developing complaints. The P10 can be seen as an indicator of sustained activation of muscle fibers, the P50 as an indicator of cumulative load and fatigue and the P90 as an indicator of mechanical overloading. It is expected that these parameters of internal load reflect different task characteristics. The frequency of an intermittent task will affect P50 and P10 above a certain threshold, but it is not expected that frequency will affect P90. The force applied in an intermittent task will affect the P50 and P90 but is not expected to have an influence on P10.

The use of subjective ratings is very common in quantifying subjective responses in experimental and occupational settings. The validity of these subjective ratings in low intensity tasks is unclear.

The aim of the present study is to evaluate the effect of two task characteristics, frequency and force, on myoelectric variables and subjective ratings during low-intensity pinching tasks.

Table 1 Subject description. Mean and standard deviation (SD) of age, length and weight

	Mean	SD
Age (years)	31	4.5
Length (cm)	179	9.2
Weight (kg)	72	10.9

METHODS

Nine healthy, right-hand dominant, subjects (5 men, 4 women) participated in the study (Table 1). The subjects performed isometric pinching tasks with the thumb opposing the index and middle finger. The subjects sat in a standardized posture with the upper arm vertically, the lower arm horizontally supported and with the wrist in a neutral position.

By using 3 force levels (5%, 10% and 20% of maximal pinching force) and 3 frequencies (pinching 2 seconds 3, 6 and 10 times per minute) nine pinch-release tasks were formed. The task duration was ten minutes as well as the rest between the tasks. The produced pinching force, the target force and the pinch - release periods were presented to the subjects on a computer screen. Additional auditive signals were given to mark the pinching periods. Previous to the tasks maximal-pinching force was measured.

EMG data of forearm muscles (m. extensor digitorum, m. flexor digitorum) and the m. trapezius pars descendens were collected, with a sample rate of 1000 Hz, during the 9th minute of each task. Bipolar Ag/AgCl surface electrodes with a recording distance of 20 mm were used. The EMG of the forearm muscles was normalized to a Standard Isometric Contraction (SIC): maximal pinching under the described task conditions. EMG data of the m. trapezius pars descendes was normalized to a maximal voluntary contraction (MVC). By using the Amplitude Probability Distribution Function (Jonsson, 1978), the static level (10th percentile, P10), the median level (P50) and peak level (P90) of the normalized EMG data were calculated.

Two types of subjective ratings were used, a more global subjective rating of the level of perceived 'cramp', 'tension', 'discomfort' and 'fatigue' on Visual Analogue Scales (VAS) and a body region specific rating of the level of discomfort on a Borg-type scale. Six body regions were marked on a body map: 'neck-shoulder', 'upper arm', 'lower arm', 'wrist', 'ring finger / little finger' and 'thumb / index finger / middle finger'.

The subjects were asked to fill out the scales before and after each task. The difference between the post and pre score was calculated.

ANOVA for repeated measures ($p < .05$), with post hoc testing was used to test for the effects of the experimental conditions.

RESULTS

Maximal pinch forces for the nine subjects were in a range of 79 N to 155 N. The low force conditions (5% MVC) varied between 3.9 N and 7.8 (N) and the high force conditions (20% MVC) varied between 15.8 N and 31.0 N.

Muscle activity

In figure 2 the normalized EMG data for the m. flexor digitorum, m. extensor digitorum and m. trapezius pars descendens are shown.

There are significant main effects of force on the P90 level of the activation of m. flexor digitorum ($F=31.2$, $p=.000$) and on the P90 level of the activation of the m. extensor digitorum ($F=10.0$, $p=.008$).

The main effects of frequency on the P10 level ($F=7.4$, $p=.019$) and on the P50 level ($F=4.9$, $p=.047$) of the activation of the m. flexor digitorum were also significant. No effects of the interaction of force and frequency on the muscle activation were found.

The post hoc results are shown in Table 2. The P90 level of the activation of the m. flexor digitorum is significantly higher in the median and high force condition than in the low force condition and is also higher in the high force condition compared to the median force condition. The P90 level of the activation of the m. extensor digitorum is significantly higher in the median and high force condition compared to the low force condition. The P10 and P50 levels of the activation of the m. flexor digitorum are significantly higher in the high frequency condition compared to the median frequency condition. The low frequency does not differ from median or high frequencies.

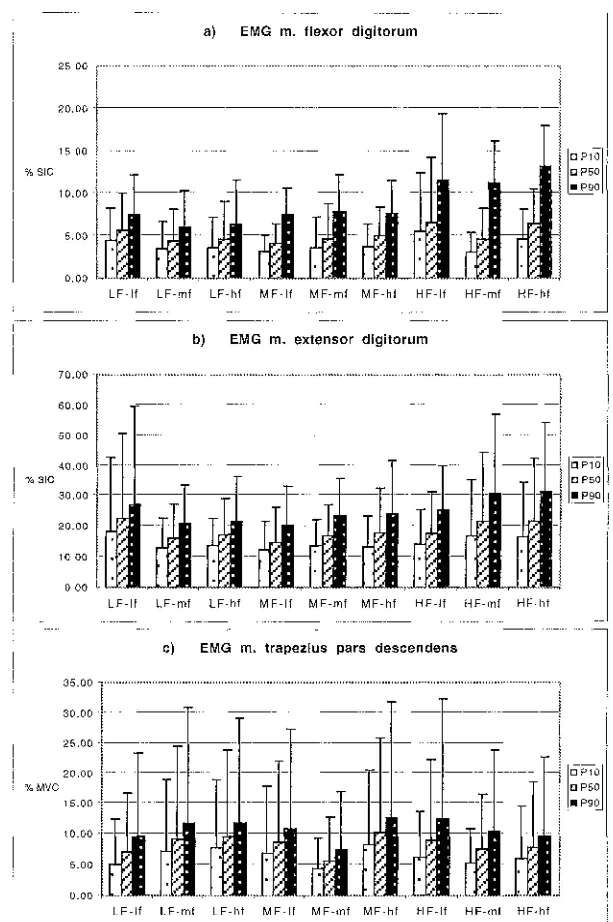

Figure 2 Static level P10, Median level P50 and peak level P90 of normalized EMG for the a) m.flexor digitorum, b) m. extensor digitorum and c) m. trapezius pars descendens. LF=Low Force, MF=Median Force, HF=High Force, lf = low frequency, mf=median frequency, hf=high frequency.

Subjective ratings

The post scores of the VAS scales were low, on a scale from 0 to 10 the mean scores were in a range from 0.6 to 3.8. Mean scores on the body region scales (ranging from 0-7) were also low, from 0.1 to 2.8.

Testing for the main effect of force and frequency leads to only one significant main effect of force on the scores of VAS tension. VAS tension scores are significantly higher in the median and high force conditions compared to the low force condition (Table 2).

Table 2 Significant differences after post hoc testing for the main effect of force on the Flexor P90, Extensor P90 and VAS tension and for the main effect of frequency on the Flexor P10 and the Flexor P50. LF=Low Force, MF=Median Force, HF=High Force, mf=median frequency, hf=high frequency.

	Force
Flexor P90	LF < MF < HF.
Extensor P90	LF < HF MF < HF.
VAS tension	LF < MF LF < HF.
	frequency
Flexor P10	mf < hf
Flexor P50	mf < hf

The interaction of force and frequency show no effect on VAS Cramp and the body region scales. Interaction effects of force and frequency are seen for VAS discomfort ($F=3.3$, $p=.02$), VAS tension ($F=6.2$, $p=.03$) and VAS fatigue ($F=3.7$, $p=.01$). In Table 3 the significant post hoc results are summarized. The post hoc tests showed no significant differences in the VAS scores on discomfort, tension and fatigue among the various low and medium force and frequency conditions. At the high force there are significantly higher scores on VAS discomfort and VAS tension at the high frequency condition compared to the low frequency condition. At the high force there is significantly higher score on VAS fatigue at the high frequency condition compared to the median frequency condition. At the high frequency there are significantly higher scores on VAS discomfort and VAS tension for the high force condition compared to the low and median force conditions. At the high frequency there is significantly higher score on VAS fatigue at the high force condition compared to the low force condition.

Table 3 Significant differences after post hoc testing for the interaction effects of force x frequency. (no significant differences were found at the low and medium force or frequency levels). LF=Low Force, MF=Median Force, HF=High Force, lf= low frequency, mf=median frequency, hf=high frequency.

	high force	high frequency
VAS discomfort	lf < hf	LF < HF MF < HF
VAS tension	lf < hf.	LF < HF MF < HF
VAS fatigue	mf < hf	LF < HF

DISCUSSION

The objective responses of the internal load are estimated by three measures, P10-P50-P90, reflecting the pattern of muscle activation. The results of the activation of the prime mover of the pinching task, the m. flexor digitorum, show that the P90 is sensitive for the effect of force. The expected sensitivity of the P50 with respect to force is not found. With respect to the effect of frequency the results match with our expectations.

The lacking effect of force on the P50 might be explained by the low intensity of the tasks. Jensen & Garde, 1998 suggest that at low force levels other factors, e.g. co-contractions and attention related demands are more related to muscle activity than the external force. Especially the low force and low frequency levels might result in higher attention and precision demands and thus in relative high muscle activation. This is a possible explanation for the lack of differences in activation of the m. flexor digitorum (P10 and P50) between low frequency conditions compared to the median and high frequency conditions. The low frequency is probably below the threshold of sensitivity of P10 and P50.

The m. extensor digitorum has a role in the stabilization of the wrist. The pattern of activation is to be expected comparable to that of the m. flexor digitorum. The results show that, except for the effect of force on P90, force and frequency do not affect the level of activation. It is possible that other stabilizing demands, f.i. keeping the hand in position, influence the activation level.

Force and frequency did not have an effect on the level of activation of the m. trapezius pars descendens. In previous studies (Veiersted et al., 1993, Jensen et al., 1993) the static and median activation levels were associated with different workload and with the prevalence of upper extremity complaints. It is possible that the trapezius activation is not influenced by the tasks because of the prescribed posture with the supported lower arm. Studies also show that EMG activity of the shoulder muscles show considerable variation between workers performing similar tasks (Veiersted et al., 1990, Schüldt et al., 1987). The large standard deviations of the activation levels in our study are in agreement with these findings.

The subjective ratings poorly reflect the external load. Only one out of the ten scales is affected by the factor force. None of the scales is affected by frequency. Interaction effects of force and frequency are only seen in three of the VAS scales and none of the body region scales. It is interesting to see that at the high frequency and high force levels differences in external load can be found with subjective ratings. The low intensity of the tasks might be the one of the reasons for the lack of discrimination of different external loads. This is in agreement with Kumar & Lechelt (1999), Chaffin et al. (1999) and Smutok et al. (1980). The short duration of the tasks can also play a role.

The implications of the results for exposure assessment in occupational settings seems that subjective ratings are not very useful when low intensities are involved. With respect to EMG it seems to be of importance to choose the proper variables in relation to task characteristics. P50 en P10 of the prime activator muscle are useful variables in evaluating the effects of task frequency above a certain threshold in task frequency. P90 of the prime activator muscle is useful in evaluating the effects of external forces. It can be concluded that the P50 does not reflect the differences in force levels in tasks with low intensities.

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